CHEMICAL TRANSPORT AND TRANSFORMATION IN LARGE SOIL CORES

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INTRODUCTION

A limiting factor in the development and testing of root/vadose zone transport models is a lack of detailed data needed to validate the model predictions (Leonard and Knisel, 1990). Laboratory studies usually fail to replicate normal variabilities in climate and soil properties. Field studies lack sufficient control over the same variables necessary to evaluate individual processes. The research described here involves development of an experimental system for the study of many processes involved in chemical transport and fate. It is anticipated that the experimental design will overcome the primary limitations of previous process-oriented research: poor representation of field conditions and inability to control the many variables influencing the processes under study. In the laboratory, many factors can be carefully controlled, however representation of natural soil/environmental conditions is sacrificed. Packed columns or small undisturbed cores may not typify the high degree of variability of natural soil properties such as conductivity, porosity, water retention, etc. Coltman et al. (1991) presented a review of the literature on the use of soil columns for solute transport studies. Soileau and Hauck (1986) and Bergström (1990) have reviewed the use of lysimeters for chemical transport studies. It is anticipated that the large (0.5 m diameter by 1.2 m long) undisturbed soil cores used in this study will be more representative of naturally heterogeneous soil properties.

This project was designed to study the fate and transport of pesticides in large undisturbed soil cores that are exposed to normal climatic conditions. Depending upon the specific questions to be answered, however, the cores may be subjected to controlled conditions such as water additions or temperature regulation.

METHODS

Each core cylinder is constructed of 16 gage galvanized sheet metal with a diameter of 50 cm and a maximum length of 120 cm. The primary components of the collection apparatus include a driving plate, a 25 ton hydraulic ram, a driving upright assembly, and earth anchors to provide a reactive force against which the ram can act to push the cylinder into the ground (Figure 1). During operation, the cylinder is slowly advanced into the ground 12 - 15 cm after which the driving upright length is adjusted and the column advanced again.

A 6 m by 12 m by 1.5 m deep concrete block pit has been constructed beneath an existing rainfall controlled shelter at the University of Georgia, Coastal Plain Experiment Station (CPES) in Tifton, Georgia. This pit houses the soil cores during experiments. The automated shelter

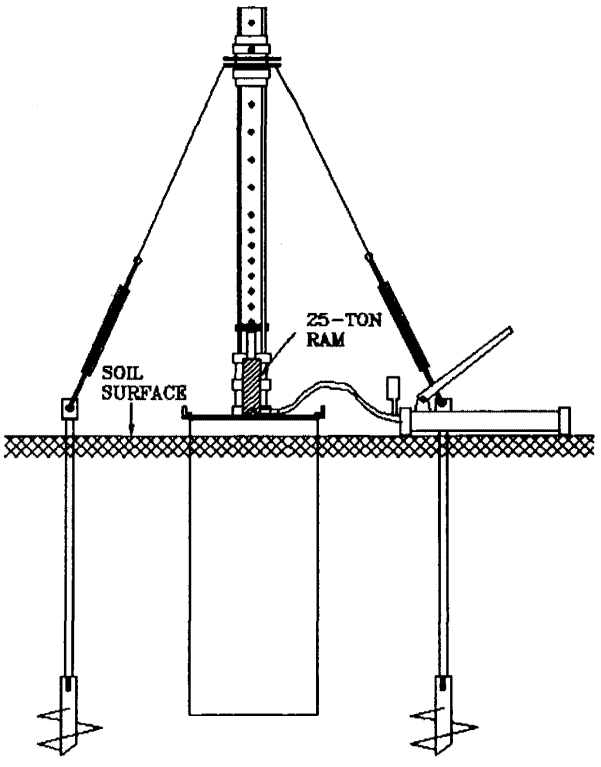

Figure 1. Schematic of soil core collection apparatus.

remains open except during rain events. Thus, the columns are exposed to normal sunlight and wind.

In general, the bottoms of the sheet metal cylinders do not have a perfectly round shape following the collection of the soil core. Therefore, bases for the columns, which contain a ceramic plate for sampling outflow, are custom fitted to each column. The bases for the columns are painted with an epoxy-based paint to reduce corrosion. Samples of steel coated with the paint have been analyzed by the USDA-ARS SE Watershed Research Pesticide Residue Laboratory for adsorption of atrazine and alachlor as well as leaching of components that may interfere with pesticide analysis. The results indicate that the epoxy paint will not interfere with the planned experiments.

Thirteen soil cores (five from Ohio and eight from Plains, GA) have been collected, instrumented, and installed in the rainfall-sheltered study facility. The Ohio cores were collected at the Ohio MSEA field research site (Workman, *et al.*, 1991) April 22-25, 1991. The cores were collected from the Huntington and Rossburg soil series (silt loams). Eight soil cores (4 cores 0.6-m long and 4 cores 1.2-m long) were collected from a pesticide transport study site in a ground water recharge area near Plains, GA during the Fall of 1991. These cores were collected in a Eustis sand.

Instrumentation and preparation of the cores includes thermocouples, small-diameter, pressure transducer-equipped tensiometers, a 280 mm-diameter porous ceramic plate on the bottom, and wrapping the cores with 25 mm-thick foil-backed insulation. During all experiments, the internal temperatures and soil water tension are read on an hourly basis using a datalogger. During preliminary studies, it was observed that the temperatures within the soil cores fluctuated over a large range and regularly exceeded 40°C. Therefore, a plywood structure was constructed around the cores to better simulate natural conditions (*i.e.* they were in the ground). The interior of the plywood structure was insulated with 25 mm-thick foil-backed styrofoam insulation. The tops of the cores are at the level of the top of the plywood. After completion of the structure the core temperatures returned to a much narrower and natural temperature range.

The cores were started on a water application and sampling regime beginning in July 1992. The water used in the experiments comes from a nearby deep-well instead of the city water supplied to the CPES. Approximately 25 cm of this water was applied to the cores over a month long period prior to the first application of chemicals. This was done in order to equilibrate the columns to the water supply and evaluate our application and sampling methodologies.

Potassium bromide was applied to all of the cores on August 21, 1992 at a rate of 100 kg-Br/ha (2.027 g/core). The bromide was applied in 2.5 mm of water. Following bromide application, water was applied to the cores at a rate of 5 mm three times per week. Sampling is done by applying a vacuum of approximately 10 inches of Hg to the bottoms of the cores for a period of 2-3 hours on the mornings prior to chemical water application. Bromide samples are analyzed using an ion selective electrode.

Atrazine and alachlor were applied to the cores at a rate of 2 kg/ha (45.4 mg AI per core) on September 10, 1992. The alachlor was an EC formulation of LASSO (4 lb AI/gallon). The atrazine was a water dispersible granule formulation called Nine-O (85% AI). Following pesticide application the water application rate was increased to 10 mm three times per week (Monday, Wednesday, and Friday). Sample collection is the same as for bromide. The pesticide samples were transported to the USDA-ARS SEWRL Pesticide Residue Laboratory for analysis. All samples are screened using ELISA for the presence of the parent compounds atrazine and alachlor. Positive samples are confirmed, and metabolites quantified, using GC.

RESULTS

Initial results from the ELISA screening tests show that the columns are all behaving quite differently. For example, the Ohio-1 core has shown atrazine levels as high as 116 μg/l (ppb) in the leachate while cores Ohio-2 and Ohio-6 have not shown concentrations above 5 μg/l, and core Ohio-5 has not shown concentrations much above the detection level (Figure 2). By contrast, the atrazine concentrations in the outflow from the 1.2-m long cores from Plains have been barely above detection levels. Atrazine concentrations in the 0.6-m long cores from Plains are much lower that the outflow concentrations from the 1.2-m long Ohio cores (Figure 3).

Alachlor concentrations in the outflow from the cores also exhibited considerable variability as shown for the Ohio cores in Figure 4. Again, the concentration of alachlor in the outflow from the 1.2-m long Plains cores was much lower (2.5 μg/l maximum) than that from the Ohio cores. Concentrations of alachlor in the outflow from the 0.6-m long Plains cores were still increasing during the time interval shown (Figure 5). These concentrations are, on average, higher than those from the Ohio cores. Notice that the transport is much more rapid through the Ohio cores than the Plains cores. This is unexpected since the Eustis soil in the Plains cores has a greater sand content and a lower organic matter content.

SUMMARY AND CONCLUSIONS

A procedure has been developed for collection and instumentation of large soil cores for use in pesticide fate/transport experiments. Each core is 500 mm in diameter and can be up to 1.2 m-long. Each core is fitted with a base containing a porous ceramic plate through

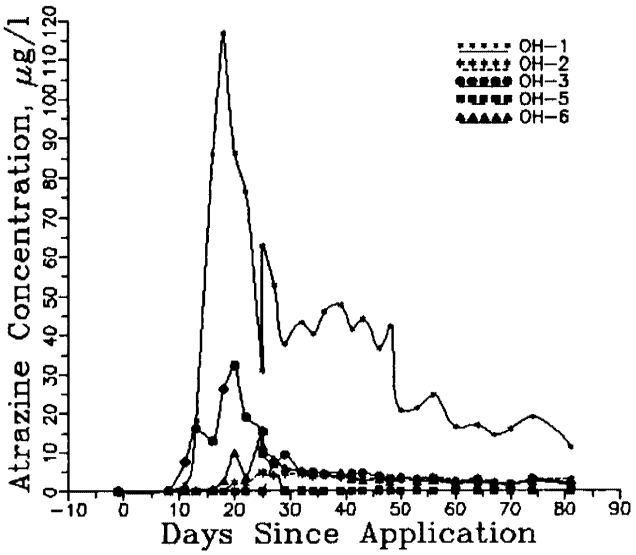

Figure 2. Atrazine concentrations in the outflow from the Ohio cores.

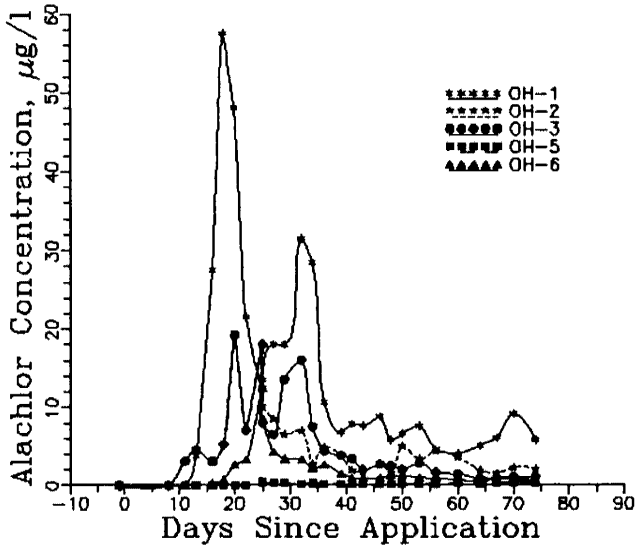

Figure 4. Alachlor concentrations in outflow from the Ohio cores.

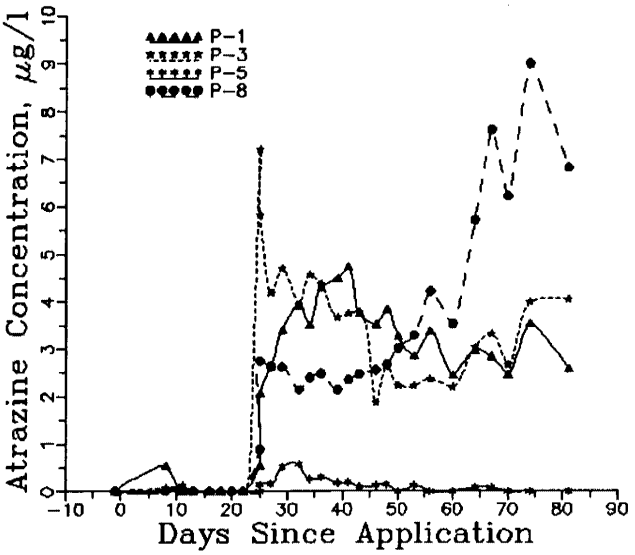

Figure 3. Atrazine concentrations in the outflow from the 0.6-m long Plains cores.

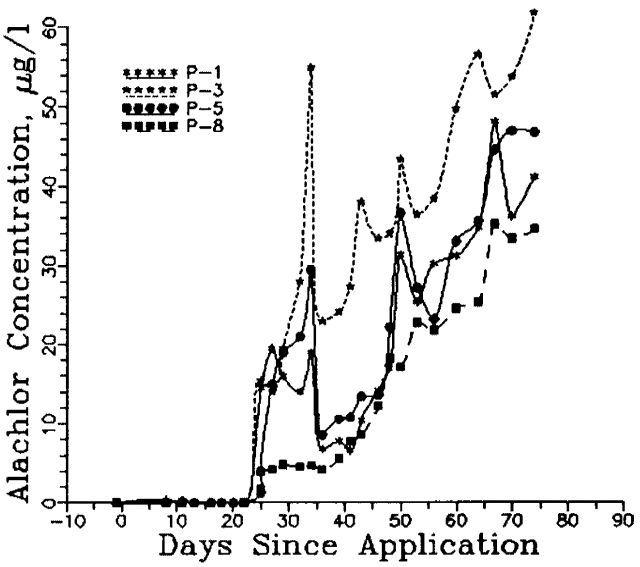

Figure 5. Alachlor concentrations in outflow from the 0.6-m long Plains cores.

which samples of the percolate from the column could be removed. This method of outflow sampling prevents the soil near the bottom of the core from always remaining saturated as would occur during gravity outflow. Each core is also instrumented with 2 or 3 (depending on the length of the core) thermocouples and tensiometers which were monitored hourly with an automated datalogging system. A facility has been developed to house the cores and expose them to natural conditions while preventing unwanted additions of water by precipitation. This facility consisted of a 12 m by 6 m by 1.5 m-deep concrete block pit beneath an automated rainfall shelter. The cores were placed in the pit such that their soil surface is at approximately the same elevation as the soil surrounding the pit.

Water additions to the cores were carefully applied to prevent surface ponding and possible preferential flow of chemical from the surface through saturated flow in large pores or cracks in the soil. The soil water potential data showed the water content within the cores was relatively uniform and, thus, that we were achieving a relatively "steady" flow through the cores with water applications three times per week. After initial problems were worked out, tensiometer data were reliable enough to suggest that movement of wetting fronts through the cores during nonsteady water additions could be observed. The temperature data will be of greater use following additional experiments when it should then be possible to relate differences in transformation rates of parent compound to the soil temperatures during the different experiments. The full benefit of this experimental system will only be achieved with numerous replicate experiments that cover a range of soil temperatures and water contents.

The results of these first experiments on the fate and transport of bromide and the herbicides atrazine and alachlor have demonstrated the usefulness of this research approach. In the field, alachlor is often not observed to leach to any significant depth, while significant leaching of atrazine has been noted by many researchers. However, in these experiments alachlor has been shown to move faster, and at higher concentrations than does atrazine. The results presented above show more alachlor than atrazine leaching through both the Ohio and Plains cores. In addition, alachlor is moving nearly as rapidly as a nonadsorbed tracer (bromide). In a field experiment on a sandy soil in Georgia, Smith, *et al.* (1990) observed no movement of alachlor below a depth of 45 cm, while atrazine moved readily through the soil profile. Initial results from the field experiment at Plains also show significantly more leaching of atrazine than alachlor through the profile (R. A. Leonard, unpublished data).

Alachlor has a published half-life of 15 days and a organic carbon partition coefficient (K_{oc}) of 170 ml/g, and atrazine has a half-life of 60 days and a K_{oc} of 100 ml/g (Wauchope, *et al,* 1992). Based on these properties, we would expect atrazine to move rapidly and persist longer than does alachlor. Further analysis of the data and comparison with results from the Ohio MSEA and Plains field studies will be required to understand the leaching behavior exhibited in the soil columns.

These experiments are continuing and future experiments with the same cores are planned. We currently plan to apply a dye tracer during the final series of leaching experiments. After completion of the experiments, the cores will be sectioned in order to observe the areas of soil within the columns contributing to flow and transport of the applied chemicals.

ACKNOWLEDGMENTS

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